

NOvA APD Cooling Water Update

William Gilbert

University of Minnesota

wgilbert@physics.umn.edu
(612) 624 4870

Heat Load & Water Flow

Assuming 5 watt (J/sec) max heat production per APD module and ignoring any heat pickup from outside module structure:

$$\text{mass/second} = (Q/\text{sec}) / (\text{spec heat} \times \Delta T)$$

$$= (5 \text{ J/sec}) / (4.186 \times 1)$$

$$= 1.19 \text{ gram/sec} = 1.19 \text{ cc/sec}$$

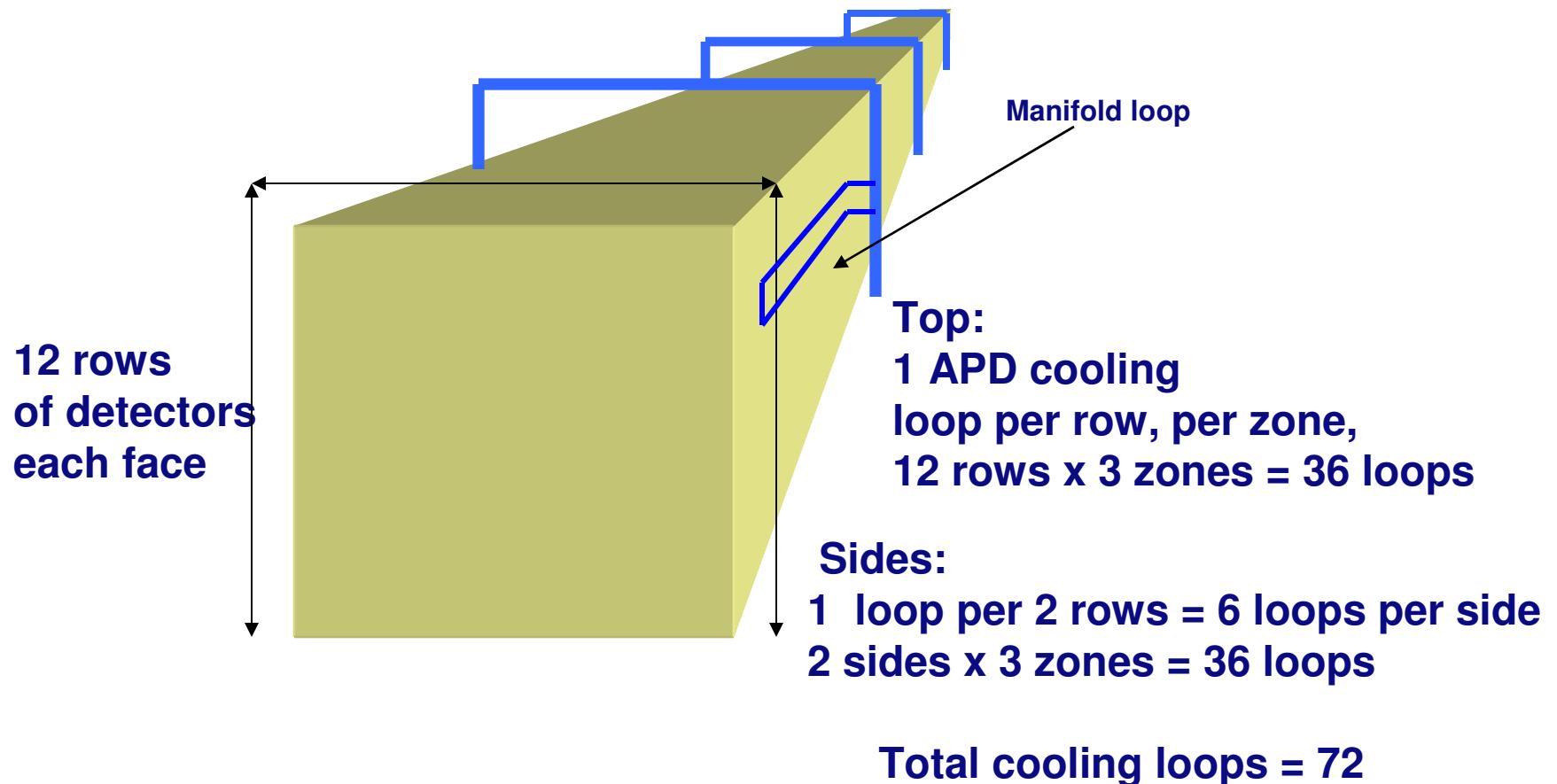
Experiments at Indiana indicate that about 2 cc/sec is the real-world number.

$$2 \text{ cc} = 0.002 \text{ L/sec} \times (0.2642 \text{ L/gal}) = 5.28 \times 10^{-4} \text{ gal/sec}$$

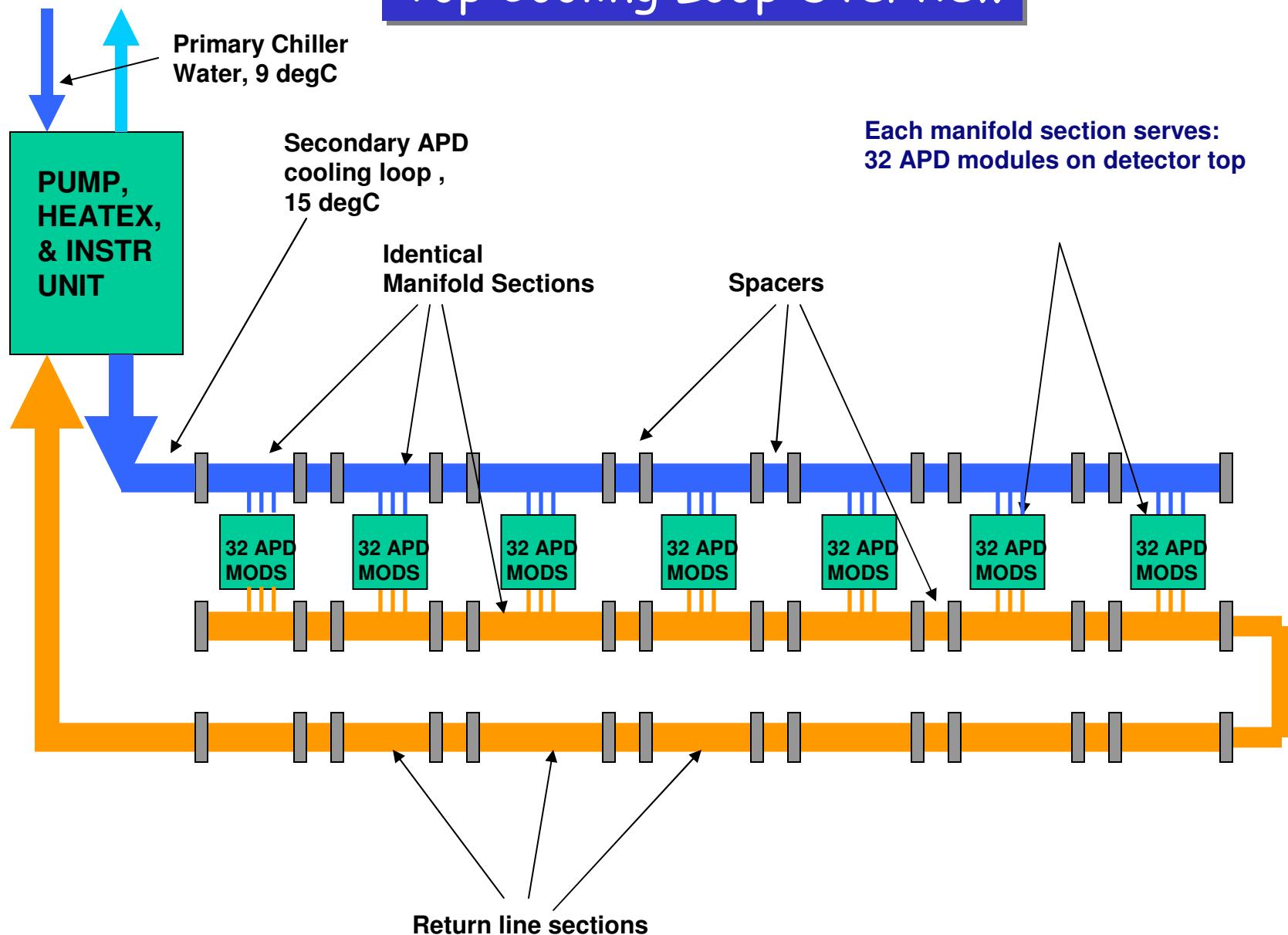
$$= 0.0317 \text{ GPM (gal/minute)} \text{ per APD module}$$

Cooling System Zones & Dimensions

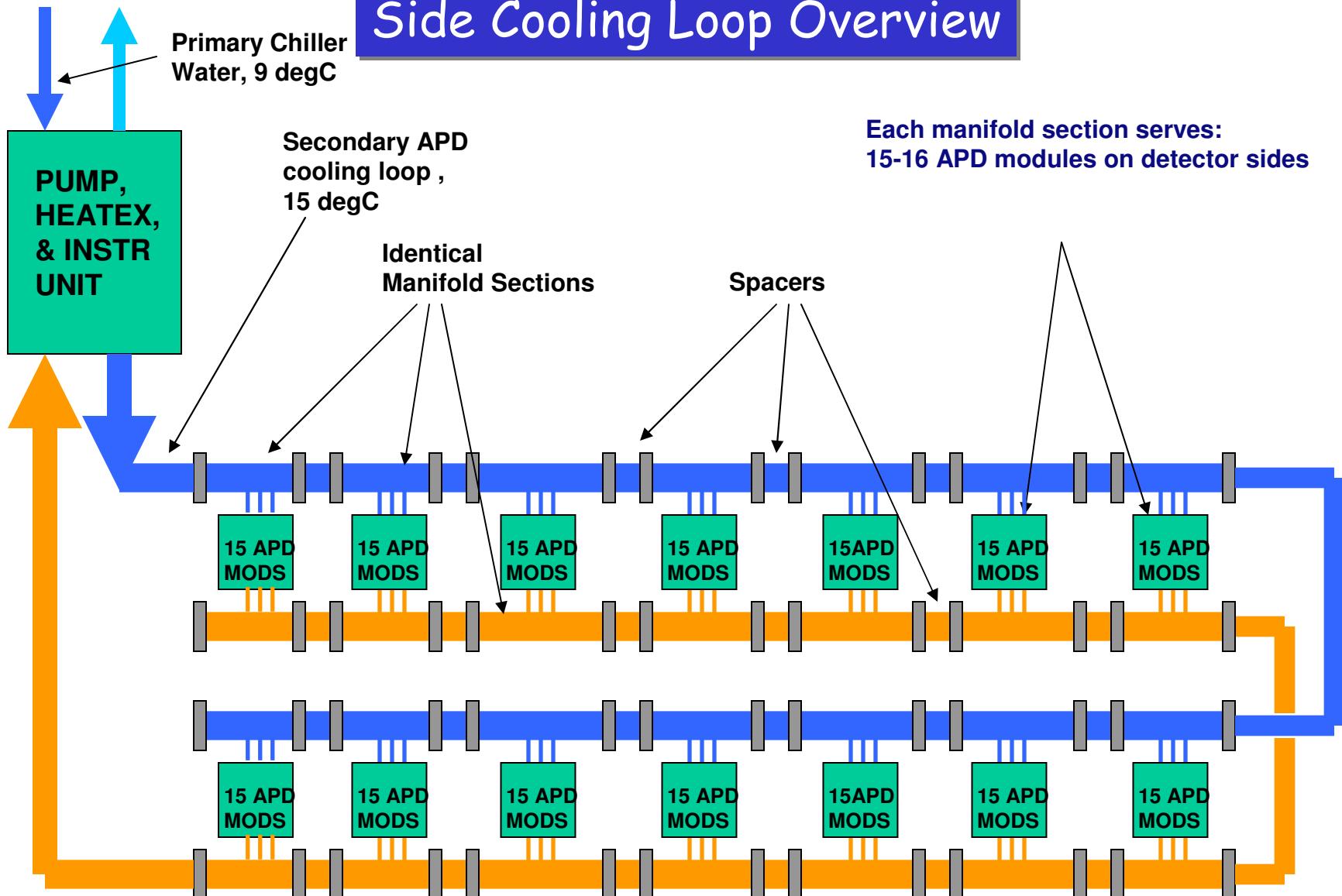
3 primary cooling zones along the length of the detector supplied by chilled water at 48 degF (8.9 degC) supplied by FESS.



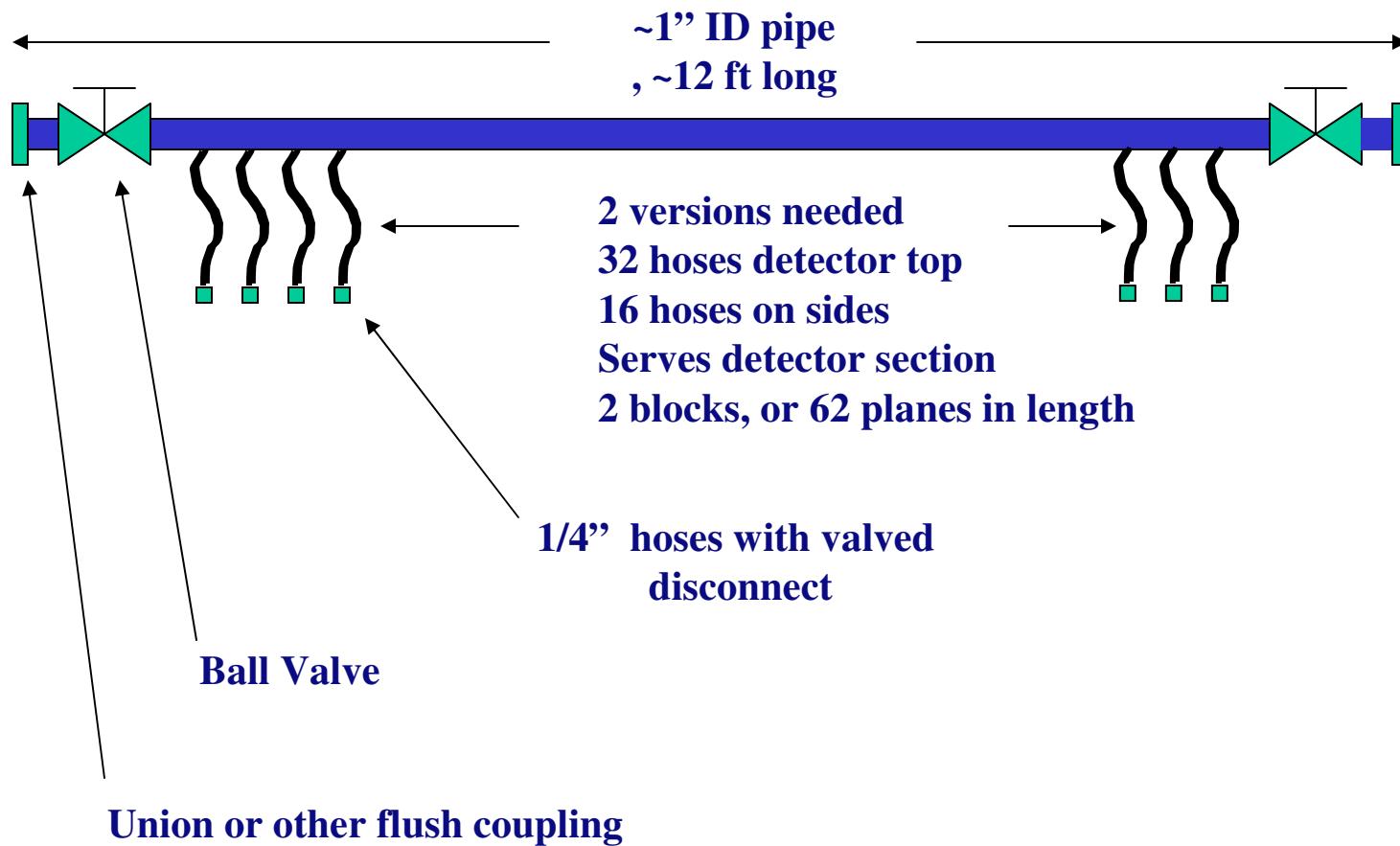
Top Cooling Loop Overview



Side Cooling Loop Overview

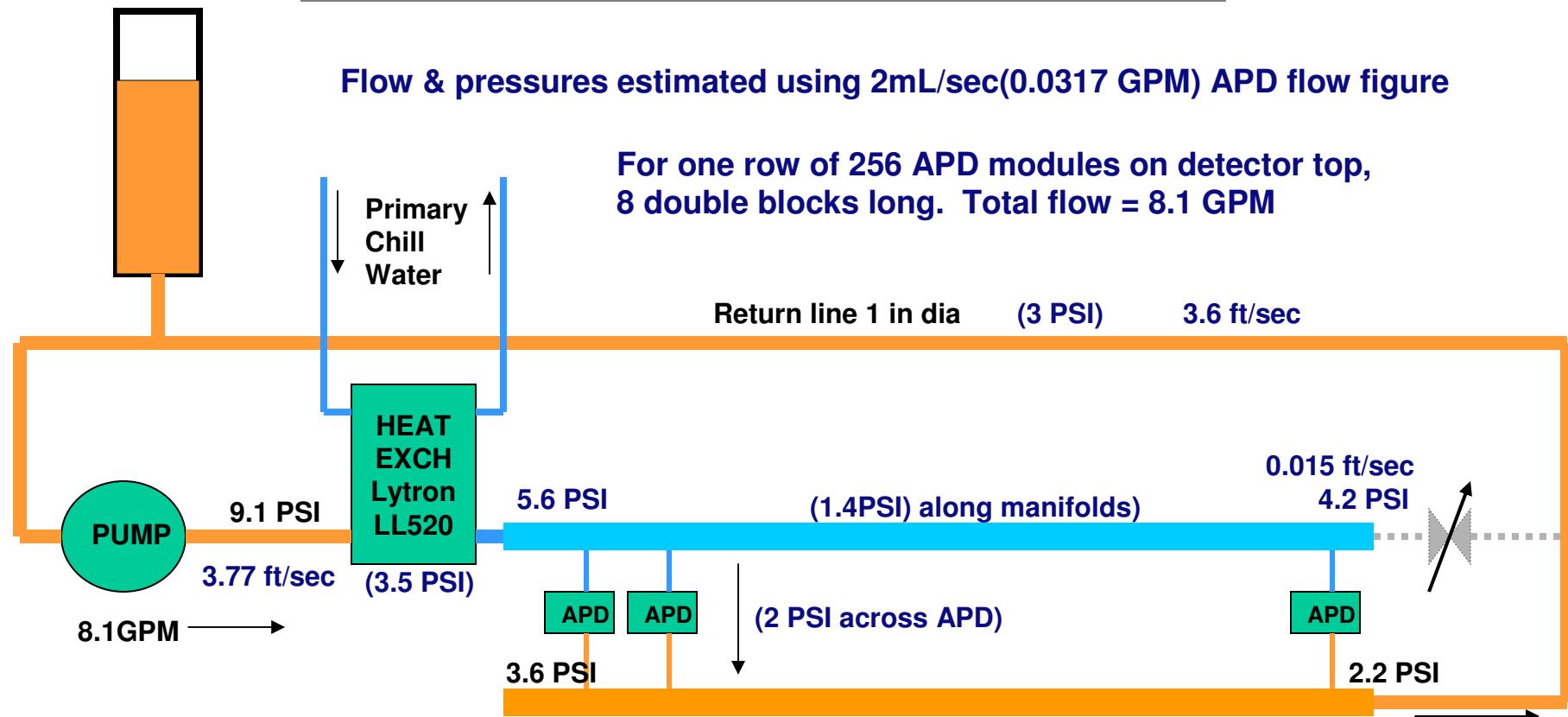


NOVA Cooling Manifold Section



Reservoir

Est. Loop Flow & Pressure

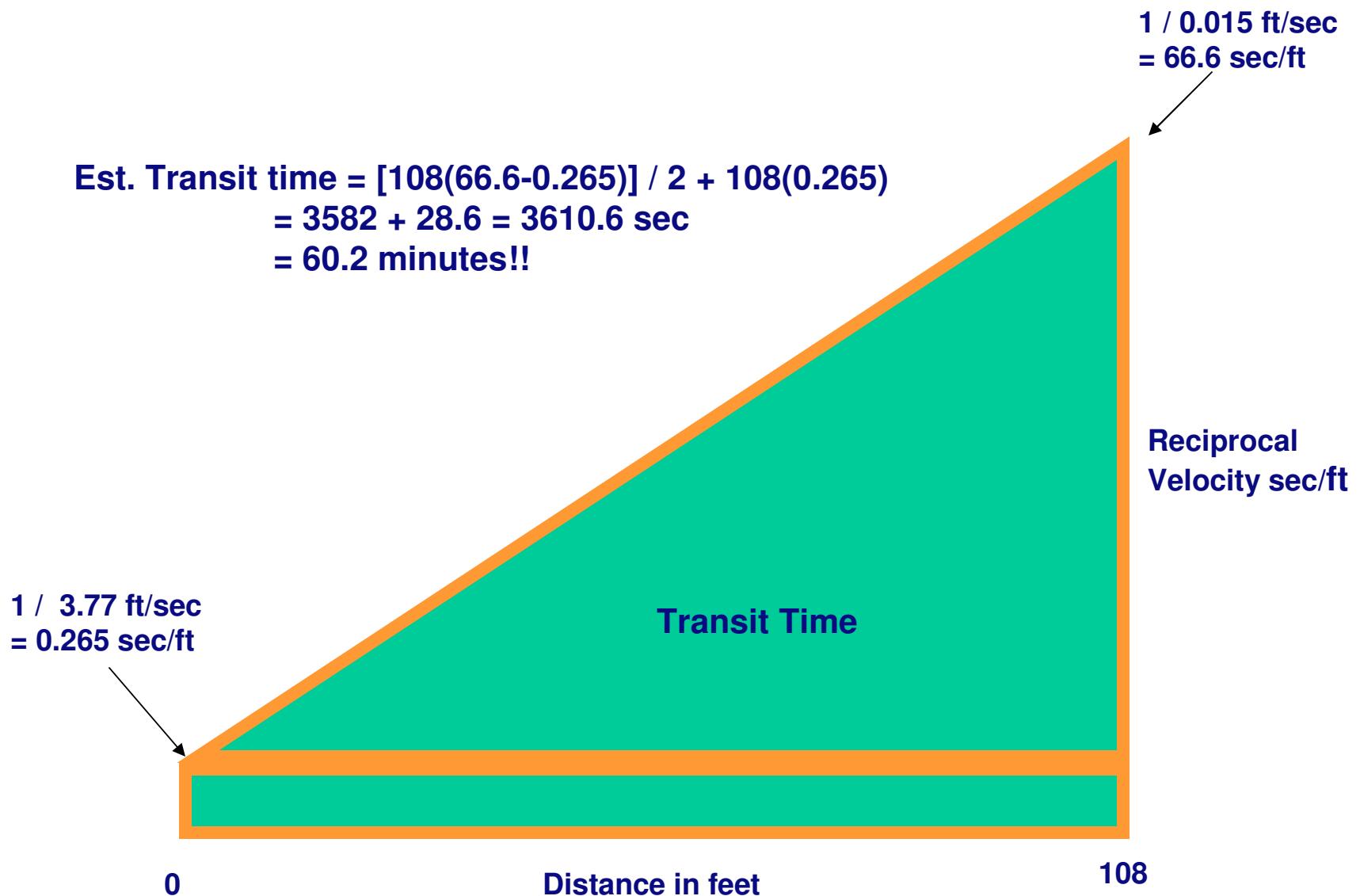


Grundfos 1/6 hp
UPS 26-99FC/FRC
@ 8.1 GPM
L 5.2 PSI
M 8.5 PSI
H 10.8 PSI

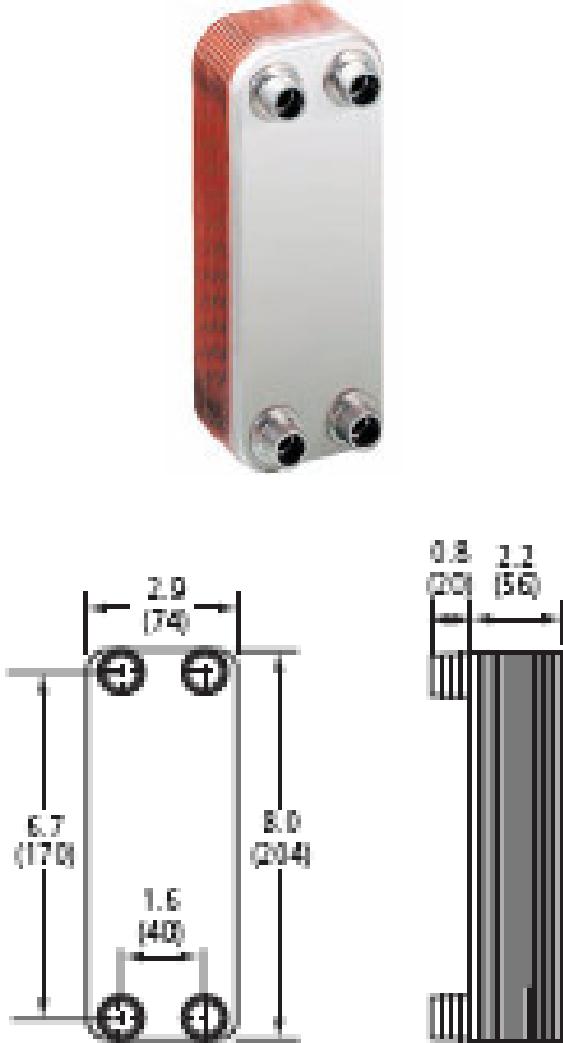
Pressure drops estimated with schedule 80 PVC, using calculator found at:
<http://www.irrigationtutorials.com/formulas.htm#sec8>

Manifold Transit Time without end bypass

$$\begin{aligned}\text{Est. Transit time} &= [108(66.6-0.265)] / 2 + 108(0.265) \\ &= 3582 + 28.6 = 3610.6 \text{ sec} \\ &= 60.2 \text{ minutes!!}\end{aligned}$$



Why Heat Exchangers?



Performance, Specifications and Ordering Information | Liquid-to-Liquid

Performance
The performance of our liquid-to-liquid heat exchangers vary with the fluid type, flow rate and temperature of each fluid. The charts below show the thermal performance for water and water (left) and water and oil (right).

Thermal Performance Using Water and Water

Flow Rate (GPM)	LL510 (Red)	LL520 (Blue)	LL810 (Green)	LL820 (Yellow)
0	0	0	0	0
2	~100	~50	~150	~100
4	~200	~100	~300	~200
6	~300	~150	~450	~300
8	~400	~200	~600	~400
10	~500	~250	~750	~500
12	~600	~300	~900	~600
14	~700	~350	~1050	~700
16	~800	~400	~1200	~800
18	~900	~450	~1350	~900
20	~1000	~500	~1500	~1000

Thermal Performance Using Water and Oil

Flow Rate (GPM)	LL510 (Red)	LL520 (Blue)	LL810 (Green)	LL820 (Yellow)
0	0	0	0	0
2	~100	~50	~150	~100
4	~200	~100	~300	~200
6	~300	~150	~450	~300
8	~400	~200	~600	~400
10	~500	~250	~750	~500
12	~600	~300	~900	~600
14	~700	~350	~1050	~700
16	~800	~400	~1200	~800
18	~900	~450	~1350	~900
20	~1000	~500	~1500	~1000

Pressure Drop Using Water

Flow Rate (GPM)	LL510 (Red)	LL520 (Blue)	LL810 (Green)	LL820 (Yellow)
0	0	0	0	0
2	~10	~5	~20	~10
4	~20	~10	~40	~20
6	~30	~15	~60	~30
8	~40	~20	~80	~40
10	~50	~25	~100	~50
12	~60	~30	~120	~60

Pressure Drop Using Oil

Flow Rate (GPM)	LL510 (Red)	LL520 (Blue)	LL810 (Green)	LL820 (Yellow)
0	0	0	0	0
2	~10	~5	~20	~10
4	~20	~10	~40	~20
6	~30	~15	~60	~30
8	~40	~20	~80	~40
10	~50	~25	~100	~50
12	~60	~30	~120	~60

Part Numbers

Core Number	LL510G12	LL520G12	LL810G12	LL820G12	LL510G14	LL520G14	LL810G14	LL820G14	
Plate material	AlSi 316L stainless steel								
Braze material	copper 99.9%								
Number of plates	10	20	10	20	10	20	10	20	
Dry Weight	lbs kg	2.6 1.2	3.7 1.7	4.9 2.1	6.7 2.9	2.6 1.2	3.7 1.7	4.9 2.1	6.7 2.9
Fittings	1/2" MNPT								
Max. operating pressure	450 psig/31 bar								
Max. operating temp.	382°F/195°C								
Min. operating temp.	-319°F/-195°C								
Max. flow rate	20 gpm/76 lpm								

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Single Loop Heat Calculations

5w per APD module x 256 units = 1280w
Assume (guess) heat pickup in pipes, etc = 1280w
Total = 2560w

$$\begin{aligned}\text{Loop delta T} &= Q(\text{watts}) / [263 \times \text{Flow(GPM)}] \\ &= 2560w / [263 \times 8.1 \text{ GPM}] \\ &= 1.2 \text{ degC}\end{aligned}$$

ITD = initial temp difference of fluids entering heat exchanger
= (APD water + del T) - FESS chilled water
= (15 degC + 1.2deg C) - 8.9 degC = 7.3 deg C

$$Q / \text{ITD for this flow \& load} = 2560w / 7.3 \text{ degC} = 350$$

Compared to high limit value, 900, from Lytron chart for this flow rate,
350 is much lower, so this is well within capacity of LL520

Component Volumes

Pipes:

Using schedule 80 PVC pipe, nominal 1" dia,
Actual I.D. = 0.936 in, O.D. = 1.315 in
Pipe Volume = 8.26 in³ per linear foot

Hoses & APD:

Using 0.25 in I.D. tubing, tube volume = 0.59 in³ per linear foot
Assuming 3 ft per APD module, tube volume = 1.77 in³ per APD
Assume 1 in³ interior volume per APD module,
Total volume of 1 APD module & hoses = 2.8 in³

Pump Unit:

4" dia x 12" reservoir	150
LL520 heat exchanger	28
pump(guess)	30
10ft pipe	80
unit total 288 in ³	

Loop Volumes

APDs & manifolds on detector top:

3 pipes x 13.4 ft x 8.26 in ³ per foot	332
+ (32 x 3 in ³ per APD module)	+ 96
1 loop pipes & APDs for 2block section	= 428 in ³
For loop 8 double blocks long, 8 x 428	3424
+Pump unit volume	+ 288
volume of 1 top loop	= 3712 in ³

APDs & manifolds on detector sides:

4 pipes x 13.4 ft x 8.26 in ³ per foot	443
+ (30 x 3 in ³ per APD module)	+ 90
1 loop pipes & APDs for 2block section	= 533 in ³
For loop 8 double blocks long, 8 x 533	4264
+ pump unit volume	+ 288
Volume of 1 side loop	=4552 in ³

Estimated Manifold Weights

Pipes:

**Sched 80 1in pipe weight, water @ 0.0361 lb/in³ x 8.26 in³/ft
1in pipe & water** **0.424 lb/ft
+0.298 lb/ft
=0.722 lb/ft**

Hoses, disconnects, & water:

**2 x 1.5 ft hose & disconnects for
each APD module, assume 0.5 lb**

Top manifolds(wet):

3 pipes x 13.4ft x 0.722 lb/ft	29 lb
32 APD modules x 0.5 lb	16 lb
Top supply/return assembly	= 45 lb, or 3.36 lb/ft tray load

Side manifolds(wet):

2 pipes x 13.4ft x 0.722 lb/ft	20 lb
15 APD modules x 0.5 lb	7.5 lb
Side supply return assembly	= 27.5 lb, or 2 lb/ft tray load

Cooling Weight per Grating Section

Top loops:

12 APD rows x 45 lb per supply/return assembly 540 lb

Side loops:

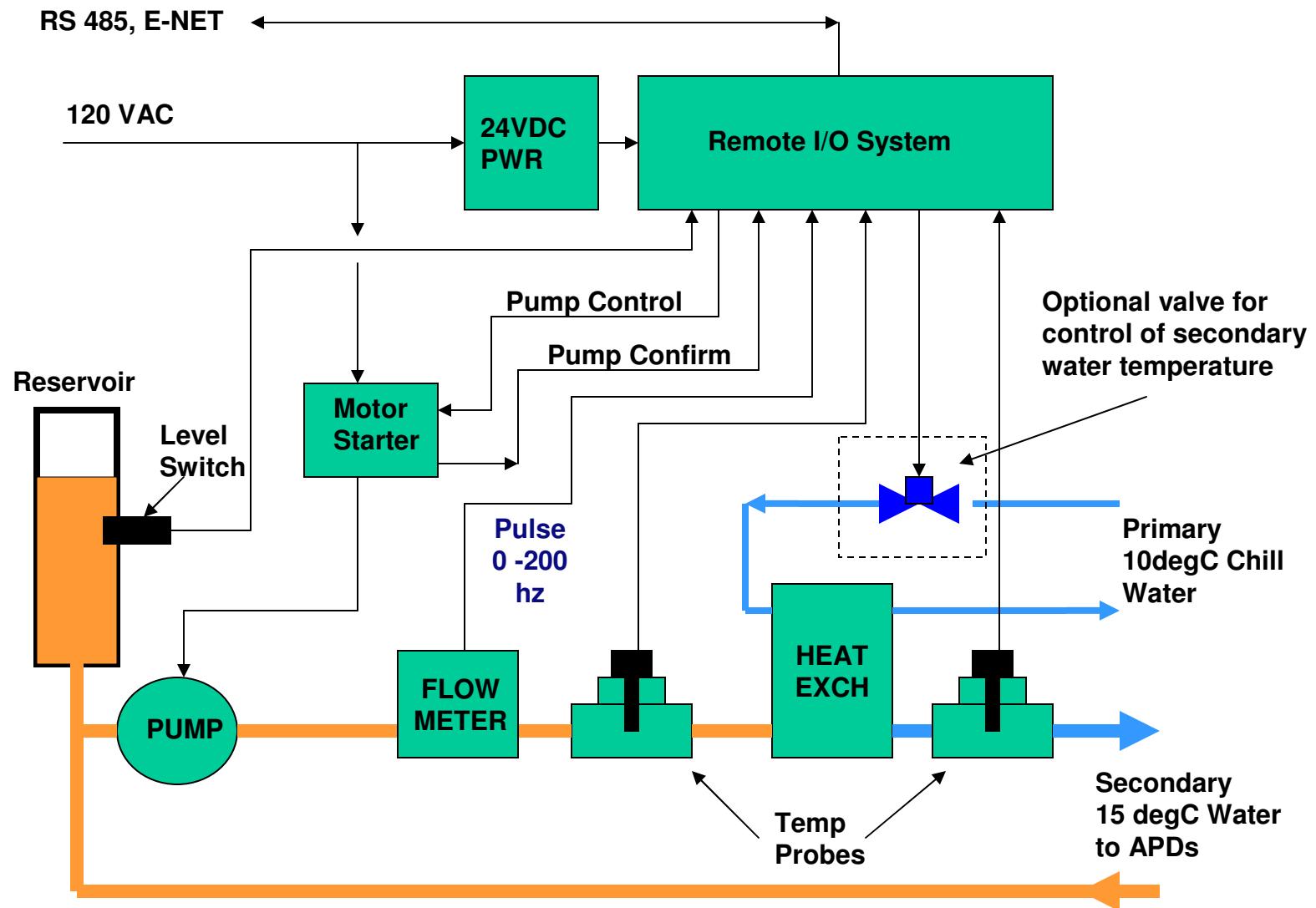
24 APD rows x 27.5 lb per supply/return assembly + 660 lb

Total wet pipe & hose weight per section = 1200 lb

Additional weight at chilled water zone headers:

24 loops x 75 lb per pump unit = 1800 lb

Pump Unit & Instrumentation



Remote I/O for Pump Units

**ADAM 5000 Series from Advantech America
looks like a good candidate:**

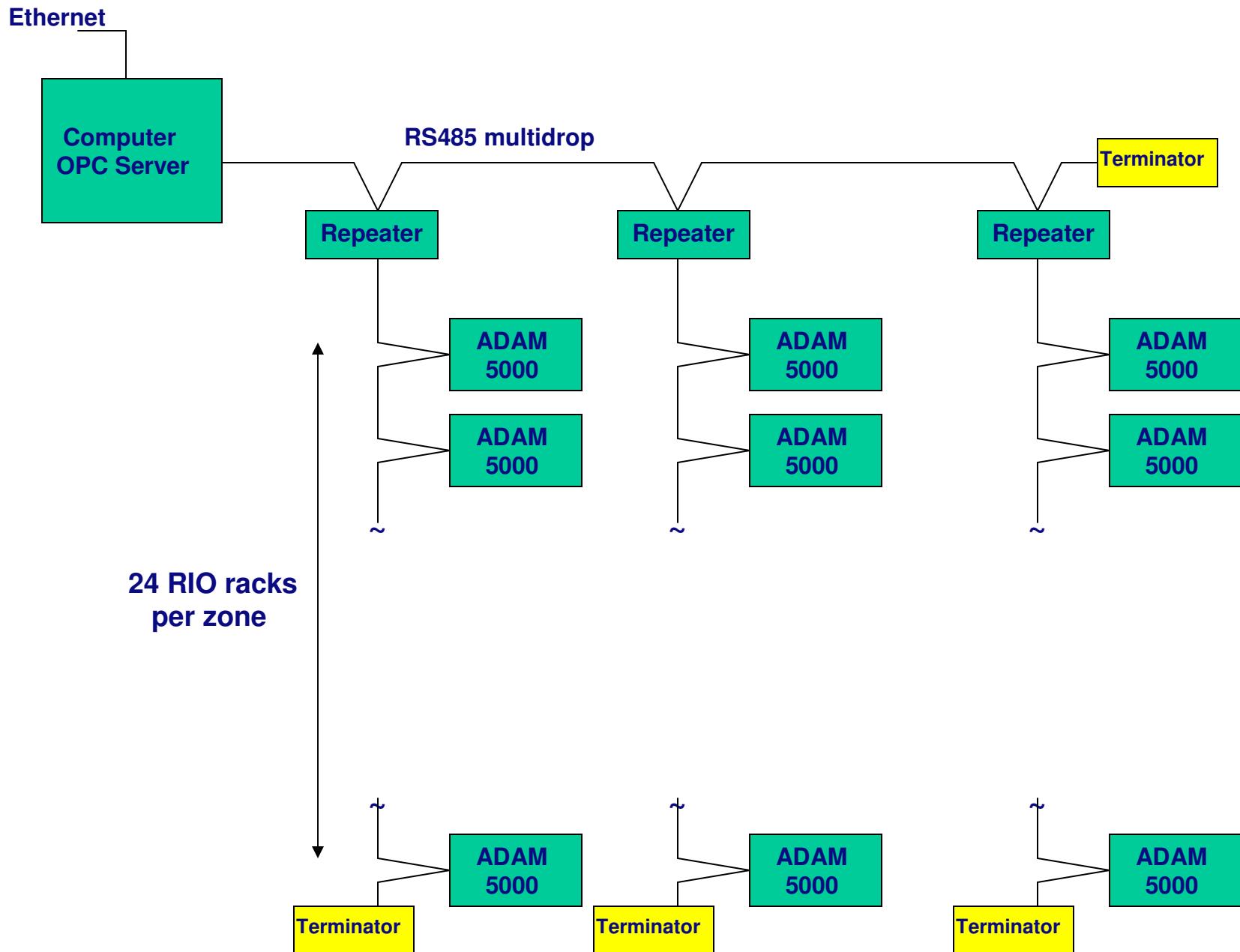


ADAM 5000/485 4 slot rack	\$ 350
ADAM 5013 3 channel RTD module	80
ADAM 5080 4 channel counter/freq module	225
ADAM 5080 discrete 8 input / 8 output module	100
	subtotal \$ 755
less 20% qty discount (151)	

our price each \$ 604

<http://www.advantech.com>
Phone: 800 205 7940

Remote I/O Network (for pumps)



Pump Unit Cost Estimate

1	Remote I/O Unit (Advantech Adam 5000)	\$ 600	\$ 600
1	Pump 1/6 hp	\$ 200	\$ 200
1	Motor Starter	\$ 120	\$ 120
1	Heat Exchanger (~LytronLL520)	\$ 200	\$ 200
1	Fluid Reservoir	\$ 50	\$ 50
1	Fluid level switch(float, capacitive, other)	\$ 80	\$ 80
2	Temp probes, RTD in welded SS fitting	\$ 50	\$ 100
1	Flowmeter (~Proteus 06008BN14)	\$ 180	\$ 180
1	24 VDC Power Supply	\$ 80	\$ 80
1	enclosure	\$ 200	\$ 200
x	Misc pipe, wire, cable	\$ 100	\$ 100
40	man-hours assembly:	\$ 50	\$ 2000
		Total	\$ 3910

New Top Loop Cost Estimate

Cost estimate for average loop on top of detector:

14.67	Top(32 tap) manifold assembly	\$ 780	\$ 11440
1	Pump & Instrumentation Unit	\$ 3910	\$ 3910
x	Misc pipe, wire, cable	\$ 100	\$ 100
24	man-hours assembly: mount 14.67 manifold sections make ~234 quick connects mount & connect pump unit & other components install wire duct, field wiring, fill, test etc.	\$ 50	\$ 1200
	single loop subtotal		\$ 16650

New Side Loop Cost Estimate

Cost estimate for average loop on side of detector:

29.33	Side(16 tap) manifold assembly	\$ 580	\$ 17013
1	Pump & Instrumentation Unit	\$ 3910	\$ 3910
x	Misc pipe, wire, cable	\$ 100	\$ 100
30	man-hours assembly: mount 29.33 manifold sections make ~234 quick connects mount & connect pump & other components install wire duct, field wiring, fill, test etc.	\$ 50	\$ 1500
	Single loop subtotal =		\$ 21523

Total Cooling Loop Cost Estimate

36	Loops, Detector Top	\$ 16650ea	\$ 599400
36	Loops, Detector Sides	\$ 21523ea	\$ 774828
Grand Total =			\$1,374,228

Old Loop Cost Estimate

SWAG cost estimate for loops on detector top, side loops a bit lower:

1	Pump 1/25hp bronze cast	\$ 150	\$ 150
1	Heat Exchanger (~LytronLL520)	\$ 200	\$ 200
16	Top manifold assembly	\$ 830	\$ 13280
1	Fluid Reservoir	\$ 50	\$ 50
1	Fluid level switch(float, capacitive, other)	\$ 80	\$ 80
2	Temp probes, RTD in welded SS fitting	\$ 50	\$ 100
1	Flow switch (~Omega FST-211-SPST)	\$ 160	\$ 160
1	enclosure	\$ 200	\$ 200
6	Remote I/O channels(2 temp, 1flow, 1 level, 1 pump status, 1 pump control)	\$ 200	\$ 1200
x	Misc pipe, wire, cable	\$ 100	\$ 100
24	man-hours assembly: mount 8 manifold sections make 512 quick connects mount & connect pump & other components install wire duct, field wiring, fill, test etc.	\$ 50	\$ 1200
	Total		\$ 16720

Use Macroflow?

Innovative Research, Inc.
3025 Harbor Lane N, Suite 300
Plymouth, MN 55447, USA
Tel:(763) 519-0105

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MacroFlow is ideally suited for system-level thermal design during the Conceptual Design stage. Its object-oriented nature enables quick construction of flow networks of cooling systems and the powerful solution method enables rapid analysis. Thus, many different system layouts, "what if" studies, and contingencies such as fan failure can be evaluated very quickly for arriving at few good system-level design early in the design cycle.

MacroFlow is a productivity tool. Its use results in significantly shorter design cycles, better product quality, and reduces the time to market.

Construction of Networks for Electronics System	Types of Cooling Systems Designed Using MacroFlow
Benefits and Limitations of MacroFlow	The Enhanced Design Cycle

SuperBrute Brochure

Advantages:

- Removable, integrated check valve does not diminish pump performance
- Eliminates the expense of an inline check valve
- Prevents thermo-siphoning
- Easily match pump performance to system requirements
- 3-year warranty



Technical Data:

Flow Range: 0 - 17 U.S.

GPM

Head Range: 0 - 19

Feet

Motor: 2 pole, Single Phase

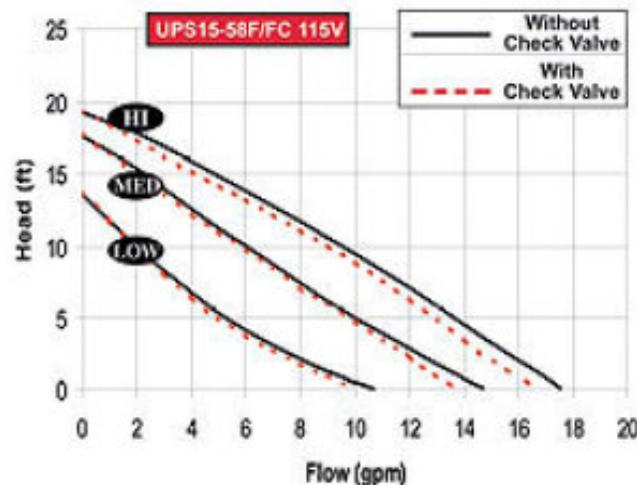
Max. Fluid Temperature Closed System: 230°F
(110°C)

Min. Fluid Temperature for UP15: 36°F (2°C)

Minimum Pressure Temp Requirements:

Competitive Cross Reference

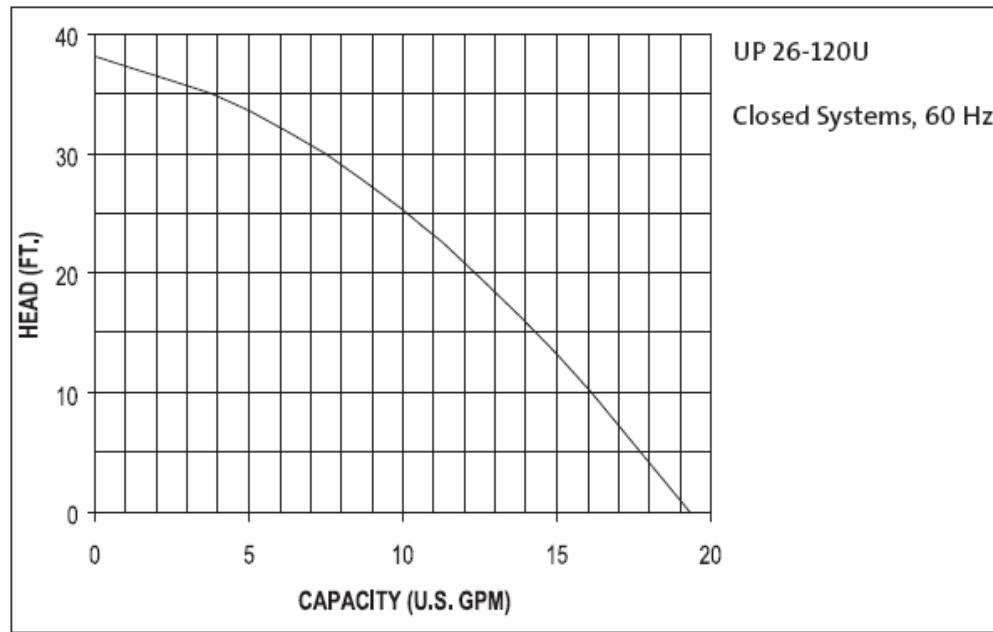
SuperBrute 3-Speed Technology replaces the following pumps:		Taco	Bell & Gossett	Armstrong
low speed	005-IFC	NRF-9F/LW		
	005			
	007-IFC			
medium speed	008-IFC	NRF-22	Astro 30	
	007			
	008			
high speed	0010-IFC			



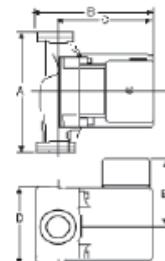
Materials of Construction:

1/4 hp Pump Data

UP 26-120U



Flow range: 0 - 19 U.S. GPM
Head range: 0 - 38 FEET
Motors: 2 Pole, Single Phase
Maximum fluid temperature: 203°F (95°C)
Min. fluid temperature for UP: 32°F (0°C)
Maximum working pressure: 145 PSI

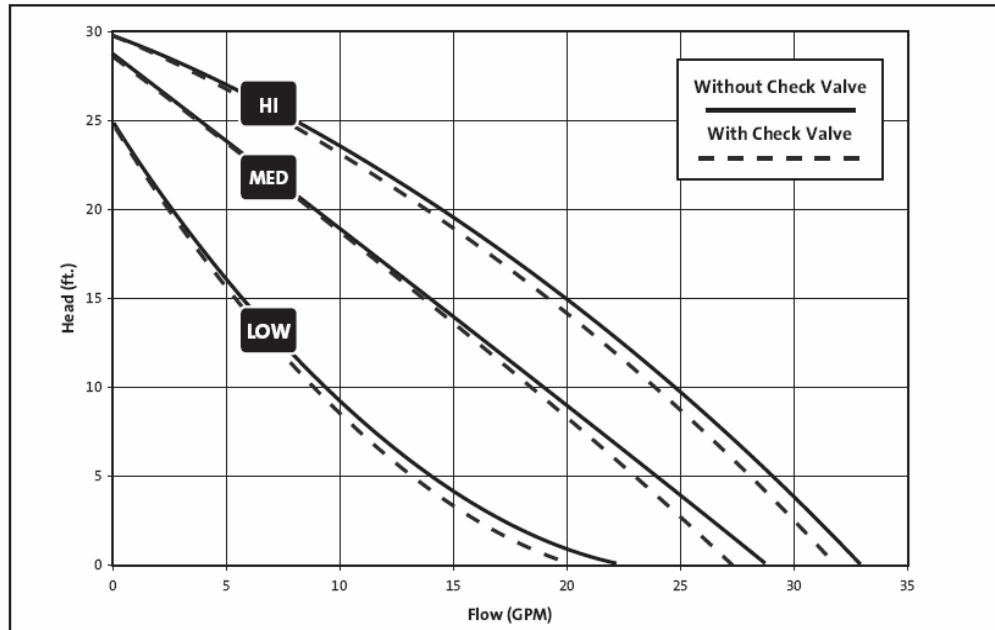


MODEL	VOLTS	AMPS	WATTS	HP	CAPACITOR
UP26-120U	115	2.15	215	1/6	10mF/180V
	230	1.07	220	1/6	2.5mF/380V

Model Type	A	B	C	D	E	Connection Type and Size	Shipping Wt. (Lbs.)
UP26-120U	7 1/16	5 7/8	5 1/16	4 7/8	3 1/2	GF 125 Union - 1 1/4" NPSM	10 1/2

1/6 hp pump data

UPS 26-99FC/BFC SUPERBRUTE



Flow range:

0 - 34 U.S. GPM

Head range:

0 - 30 FEET

Motors:

2 Pole, Single Phase

Maximum fluid temperature:

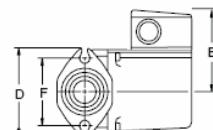
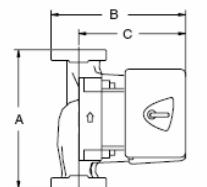
230°F (110°C)

Min. fluid temperature:

36°F (2°C)

Maximum working pressure:

145 PSI

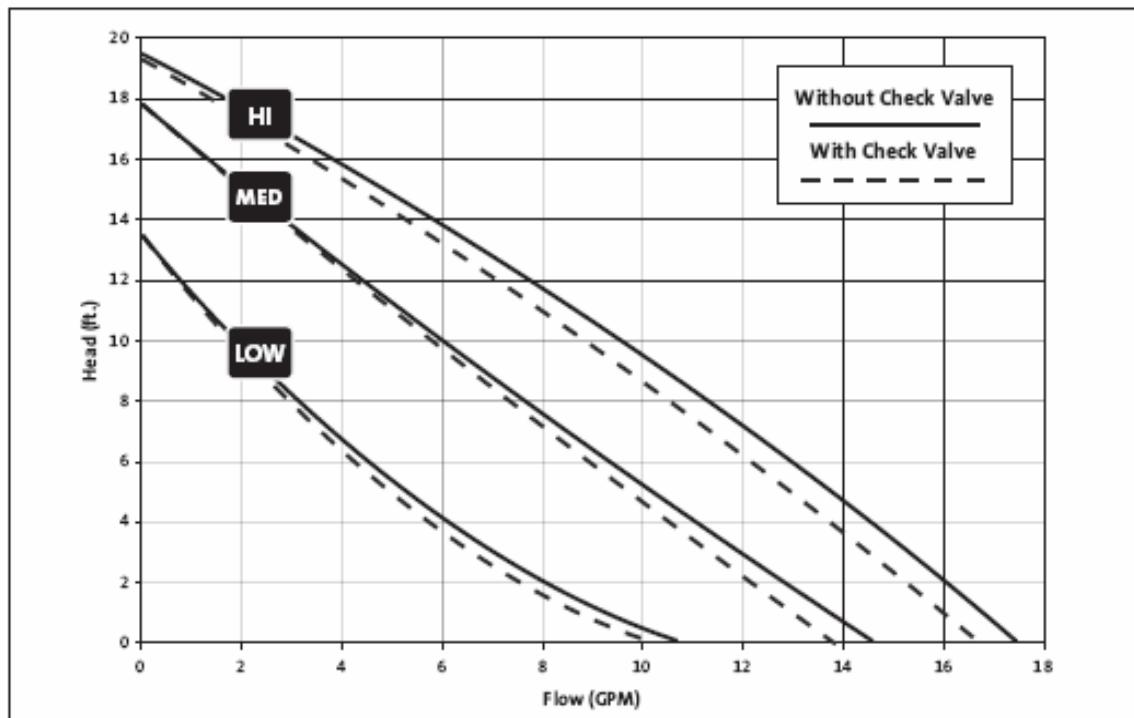


MODEL	VOLTS	AMPS	WATTS	HP	CAPACITOR
115V	Spd. 3	1.8	197	1/6	20mF/180V
	Spd. 2	1.5	179	1/6	20mF/180V
	Spd. 1	1.3	150	1/6	20mF/180V
230V	Spd. 3	0.9	196	1/6	5mF/400V
	Spd. 2	0.8	179	1/6	5mF/400V
	Spd. 1	0.7	150	1/6	5mF/400V

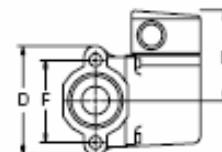
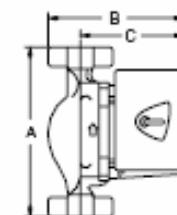
Model Type	A	B	C	D	E	F	Connection Type and Size	Approximate Shipping Wt. (lbs)
UPS26-99FC/BFC	6 1/2	6	4 7/8	3 1/2	3 7/16	3 5/32	GF 15/26 Flange - (2) 1/2" Dia. Bolt Holes	10.3

1/25 hp pump data

UPS 15-58FC/FRC SUPERBRUTE



Flow range: 0 - 17.5 U.S. GPM
Head range: 0 - 19 FEET
Motors: 2 Pole, Single Phase
Maximum fluid temperature: 230°F (110°C)
Min. fluid temperature: 36°F (2°C)
Maximum working pressure: 145 PSI



UPS15-58FC/FRC		AMPS	WATTS	HP	CAPACITOR
115V	Spd. 3	0.75	87	1/25	10mF/180V
	Spd. 2	0.66	80	1/25	10mF/180V
	Spd. 1	0.55	60	1/25	10mF/180V